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PERCEPTION OF THE HORIZON PREDICTS BIRD ABUNDANCE BETTER THAN HABITAT PATCH SIZE IN A TIDAL MARSH SPECIES OF CONSERVATION CONCERN

by

Hallie A. Marshall

A Thesis Submitted in Partial Fulfillment
of the Requirements for a Degree with Honors
(Wildlife Ecology)

The Honors College

University of Maine

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Abstract

The Saltmarsh Sparrow (*Ammodramus caudacutus*) is a tidal marsh bird species facing rapid population decline throughout its range. A major cause of this decline is degradation and loss of breeding habitat, and thus there is a need to preserve coastal marshes in the northeastern United States. To do so requires an understanding of the habitat features that support robust populations. Previous studies have shown increases in Saltmarsh Sparrow abundance with marsh size increases. In other grassland bird species, habitat patches with low horizons are preferred to those with tall objects (e.g., trees, telephone poles, wind turbines). This study tests how the abundance of Saltmarsh Sparrows is affected by the maximum height of objects in the horizon of marshes. Abundance data were collected via point count surveys at 1,698 points from Maine to Virginia during the 2012 breeding season. At each of these points, a clinometer was used to determine the height of objects in the horizon. Using program R, we evaluated detection and site covariates to determine the model which best predicted the abundance of Saltmarsh Sparrows. Our study found that the angle to the maximum horizon, which considers a bird's perception of its surroundings, is a better predictor of abundance than marsh patch size. We found that the highest abundance of this species was observed in marshes where the angle to the horizon was zero degrees, and at angles greater than 13 degrees the predicted abundance fell below one bird per point. This implies that perceived openness, rather than a large area, is selected by this species, and should be a prioritized marsh characteristic for the conservation of Saltmarsh Sparrows.

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INTRODUCTION

North American tidal marshes house more endemic vertebrates than any other coastal marsh system in the world (Greenberg et al. 2006). These marshes are facing rapid degradation and loss due to coastal development, as well as a rate of sea level rise which is faster than the global average (Wiest et al. 2016). Many populations of North American tidal marsh specialists are declining rapidly in the face of this habitat loss (Correll et al. 2017). There is a clear need to preserve coastal marshes in the northeastern United States, but to do so requires an understanding of the habitat features that support robust populations. This study investigates the viability of using one marsh feature as a predictor of Saltmarsh Sparrow abundance, with an aim to provide tools for prioritizing marshes for conservation of the species.

The Saltmarsh Sparrow (*Ammodramus caudacutus*) is one species of tidal marsh bird facing decline throughout its range (Correll et al. 2017). A ground-nesting species, the Saltmarsh Sparrow is impacted by increased severity of flooding and storm events due to anthropogenic climate change (Gjerdrum et al. 2008, Wiest et al. 2016, Correll et al. 2017). Recent estimates suggest that nearly 80% of Saltmarsh Sparrow nests fail due to flooding (Ruskin et al. 2017), and this number will increase under even minute increases in sea level (Bayard and Elphick 2011). Consequently, Saltmarsh Sparrows exhibit the highest rate of annual population decline (-9.0%) of any tidal marsh bird species in the northeastern United States and are projected to become extinct within the next 50 years if conservation action is not taken (Field et al. 2016, Correll et al. 2017).

Saltmarsh Sparrows require immediate conservation efforts to protect the remaining population, and our current understanding of the species suggests that larger marsh patches may be important. Saltmarsh Sparrows are area-sensitive (Robbins et al. 1989, Shriver et al. 2010) and select for large marsh patches (Benoit and Askins 2002). Past studies have found similar behavior for other grassland *Ammodramus* sparrows (Bakker et al. 2002, Thompson et al. 2014). However, Keyel et al. (2012) show that the relationship between patch area and small grassland bird abundance is due to habitat openness, rather than area *per se*. The authors compared models of area, edge geometry, and openness, and found that Bobolink (*Dolichonyx oryzivorus*) density was best predicted by the average angle to the horizon in a grassland patch (Keyel et al. 2012). This suggests that Bobolinks, and likely other similar birds considered area-sensitive, make decisions to occupy habitat patches based on their perception of openness.

Similar studies have shown that in other grassland birds, habitat patches with low horizons that lack elevated structures are preferred to those with tall objects (e.g., trees, telephone poles, wind turbines; e.g., Bakker et al. 2002, Ribic et al. 2009, Thompson et al. 2014), but the extent to which these results can be expanded to marsh systems is less well-known. Marshes bordered by trees or containing tall objects may be avoided due to the probability of predators using these objects as perches from which to spot prey (van der Vliet et al. 2008, Andersson et al. 2009). Additionally, individual birds may perceive marsh area differently from how humans delineate marsh patches from aerial imagery. If Saltmarsh Sparrows assess habitat similarly to other grassland birds, marsh patches may be rendered unsuitable by a narrow band of trees or powerlines. Regardless of the specific mechanism driving habitat selection, it is important to understand the characteristics that Saltmarsh Sparrows are selecting to make conclusions about which marshes to prioritize for conservation.

We used point count data to evaluate patch area and the height of objects within and surrounding tidal marshes as predictors of Saltmarsh Sparrow abundance. We hypothesized that abundance in marshes from Maine to Virginia would be better predicted by openness, defined by the maximum height of objects in the horizon of marshes, than by area.

METHODS

Field Methods

Saltmarsh Sparrow abundance was estimated with point count surveys consisting of five minutes of silent observation followed by a series of secretive marsh bird callbacks. As the callback portion of these surveys varied by region, we only used bird counts from the five-minute silence period to remain consistent across the range. During point count surveys, all birds observed by sight and sound were reported at estimated distances bands (<50, 50-100, >100 meters) and we used the sum of birds across all distance bands in our analysis. Surveys were conducted two to three times at each randomly placed point from April 15 to July 31, 2012 in tidal marshes from Maine to Virginia. All points were located a minimum of 400 meters apart, and recurring surveys at each point were completed a minimum of ten days apart. Surveys were conducted from 30 minutes before sunrise to 11:00am local time (Wiest et al. 2016).

During each point count survey, data were collected on survey conditions including: (1) noise interference on a 0 to 4 scale (0 = no interference, 4 = probably cannot hear birds beyond 25m); (2) wind speed based on the Beaufort Scale; (3) sky condition using U.S. Weather Bureau codes; (4) temperature in Fahrenheit; (5) time of day; and (6) survey window (Early, Mid, Late). These variables are henceforth referred to as our survey covariates. To avoid detection bias, surveys were not conducted when wind speed was greater than 20 kilometers per hour, when noise prevented detection of birds within 50 meters, or when there was sustained fog or rain (Wiest et al. 2016).

Using a clinometer and compass, we also collected openness information at each survey location during the field seasons of 2012, 2013, or 2014 (SHARP 2013). We used a clinometer to record the vertical angle, and compass to record the azimuth, to the tallest object visible on the horizon (maximum horizon) from the point, regardless of direction or proximity of the object. We also used clinometers to record the vertical angle to the horizon in each cardinal direction, and used the mean of these four measurements as the average angle to the horizon at each site. When objects on the horizon were at eye-level or lower (i.e., a very open marsh), the maximum horizon was zero degrees. The tallest objects produced a maximum angle of 90 degrees.

Marshes were delineated as individual patches by SHARP using the National Wetlands Inventory Estuarine Intertidal Emergent Wetland layer (U.S. Fish and Wildlife Service National Wetlands Inventory 2010) and ArcGIS (Wiest et al. 2016). Patches were defined by discrete spatial areas of contiguous marsh vegetation (Wiest et al. 2016). Patch area was calculated in hectares using this GIS software. Many marsh patches contained more than one survey point, which were distributed and randomly selected in patches using program R (R Core Team 2016). We recorded the latitude of each point to account for unequal distribution of Saltmarsh Sparrow populations across the breeding range. Collectively all measurements associated with each survey point are henceforth referred to as our site covariates.

Data Analysis

We implemented *N*-Mixture (Royle 2004) models in a generalized linear model framework using program R (R Core Team 2016) and the package unmarked (Fiske and Chandler 2011) to fit survey- and site-specific covariates to counts of Saltmarsh Sparrows at each site, while accounting for imperfect detection among repeated surveys. These models were built in a generalized linear model framework, which accommodates a non-normal distribution of the data. We first tested for the best approximating distribution of sparrow density, and found that a negative binomial distribution outperformed zero-inflated Poisson and Poisson distributions, and so we fill all models under a negative binomial.

We began by testing survey-level covariates that might potentially affect detection. Noise level during a survey was tested because Saltmarsh Sparrows have a relatively quiet call that is not easily detected from distances greater than a few meters even in low-noise conditions (Greenlaw and Rising 1994). We tested wind speed because higher wind speeds may delay singing (Bruni et al. 2014) and also make it more difficult to hear sparrow songs. We tested temperature to account for the changing frequency of singing at differing temperatures (Thomas 1999). Sky condition, an index of the cloud cover and weather during a survey, was included because cloud cover and weather affect when birds sing (Bruni et al. 2014). Time of day (converted to a continuous scale of hours after midnight) was tested because birds sing more frequently in the early morning hours compared to late morning hours (Bruni et al. 2014). We included survey window to account for changes in bird song activity at different stages in the breeding season (Slagsvold 1977). These covariates are related to one another and in conjunction affect both the frequency at which birds sing and potentially our ability to detect Saltmarsh Sparrows. The latitude of each point was added as a site covariate to all detection models, including the null, to account for the fact that average marsh area changes throughout the latitudinal range, peaking around New Jersey and the Atlantic coast of the Delmarva Peninsula (Wiest et al. 2016). Latitude was tested as a quadratic variable because the population of Saltmarsh Sparrows is known to peak at the same latitudes where average marsh size is largest (Wiest et al. 2016). All detection covariates which performed better than the null model (based on criteria described below) were retained and combined to produce the model which best fit the detection process.

We next evaluated the effect of site covariates on Saltmarsh Sparrow abundance, while accounting for the effect of the survey covariates that we found to affect detection. Site covariates included marsh area, maximum angle to the horizon, and average angle to the horizon. We considered linear effects of all site covariates, and also tested for a quadratic effect of maximum horizon because we hypothesized that a threshold may exist beyond which Saltmarsh Sparrow density changed exponentially. We tested the area of patches, as previous studies have found higher abundances of Saltmarsh Sparrows as area increases (Benoit and Askins 2002, Shriver et al. 2010). We tested maximum angle to the horizon of a marsh in any direction to account for the possibility that anything ranging from one large object to the entire border of a marsh could impact abundance. Average angle to the horizon was tested as an index more representative of the openness of the entire patch (Keyel et al. 2012).

Models were evaluated using Akaike Information Criterion (AIC) and models which fell within 2.0 ΔAIC of a competing model were considered equivalent. Top-ranking models were those with ΔAIC ≤ 2.0. We also examined 95% confidence intervals around parameter coefficients and the Z-score of each coefficient for top-ranking models *post hoc* to assess parameter significance.

RESULTS

We used data from 4,952 point count surveys which took place from April 15 to July 31, 2012, at 1,698 randomly-placed points in tidal marshes from Maine to Virginia. These points were distributed across 552 individual marsh patches. We observed a total of 1,080 Saltmarsh Sparrow detections, which ranged from 0 to 11 birds counted in a single survey ($0.21 \pm 0.74 = 0.0 \pm 0.95$).

Our best-supported model of detection probability (Table 1) combined the covariates of noise level, wind speed, and survey window in detection of Saltmarsh Sparrows with a model weight of 0. Temperature, sky condition, and time of day did not perform better than the null model and were not included in the second round of modeling. Survey window was positively related to detection of Saltmarsh Sparrows ($\beta = 0.06$; 95% CI = -0.01 to 0.13). Wind speed also showed a positive correlation ($\beta = 0.08$; 95% CI = 0.0 to 0.16), but this parameter may be associated with noise level, which was negatively correlated ($\beta = -0.15$; 95% CI = 0.05 to 0.25) with Saltmarsh Sparrow detections. The quadratic effect of latitude was supported (Table 3), where density peaked at south-central latitudes (Figure 1).

Table 1. Model results, including ΔAIC, number of parameters (k), and model weight (w_i) from models of detection for Saltmarsh Sparrows surveyed during 4,952 point counts from Maine to Virginia, May-July 2012. Models were run using the package unmarked in program R. All models include latitude (quadratic) as a covariate.

Model	**K**	**ΔAIC***	w_i
noise + wind speed + survey window	8	0.0	0.53
noise + wind speed	7	1.2	0.29
noise + survey window	7	3.7	0.09
noise	6	3.7	0.08
wind speed + survey window	7	10.5	0.003
wind speed	6	12.2	0.001
survey window	6	12.9	0.001
null	5	13.4	<0.001
hours after midnight	6	13.9	<0.001
sky condition	6	14.0	<0.001
temperature	6	14.6	<0.001

*log-likelihood of the top ranked model is -2183.124

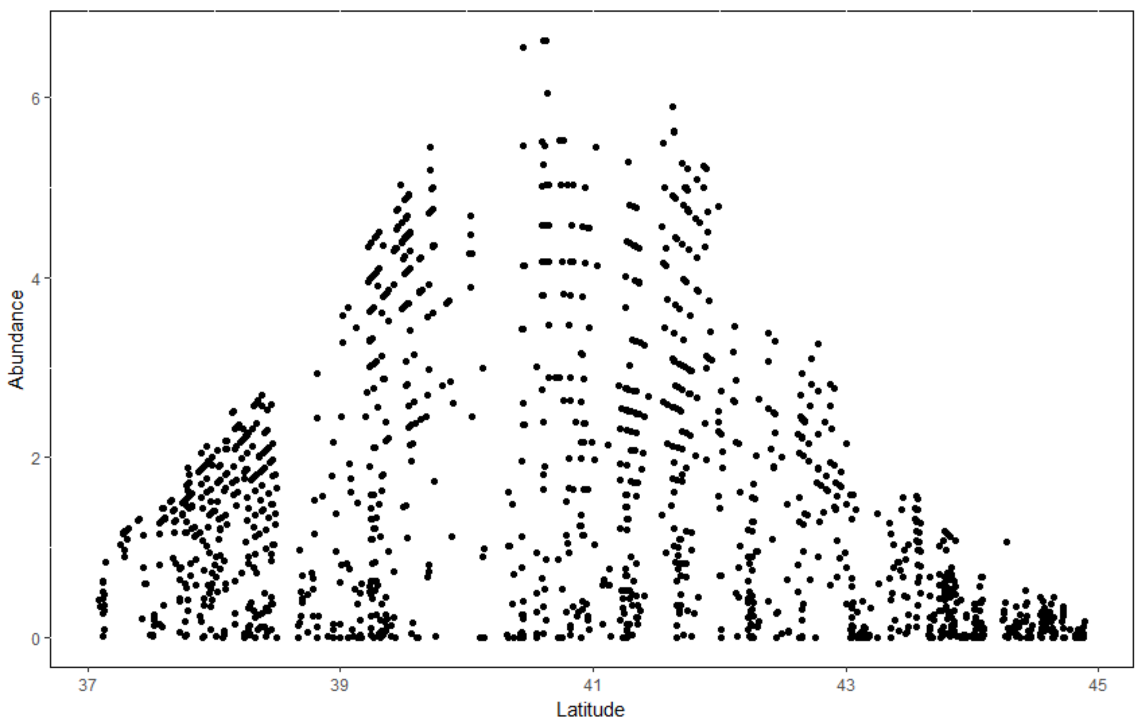

Figure 1. Predicted abundance of Saltmarsh Sparrows by latitude across the entire breeding range at all degrees of openness

The density model (Table 2) which best fit our data included a covariate of angle to maximum horizon with a weight of 0.72. The quadratic variable of maximum horizon fell within 2.0 ΔAIC of our best model, suggesting there could be a threshold at which Saltmarsh Sparrow abundance changed significantly. Average angle to the horizon was not supported (ΔAIC = 19.5) and the model with patch area instead of horizon measurements was our least competitive model, with a weight of <0.0001 (ΔAIC = 210.3). The patch area model had a similar ΔAIC and weight to the null model (ΔAIC = 208.3).

Table 2. Model results, including ΔAIC, number of parameters (k), and model weight (w_i) from models of abundance for Saltmarsh Sparrows surveyed during 4,952 point counts from Maine to Virginia, May-July 2012. Maximum angle to horizon data were collected during 2012-2014 and patch areas in hectares were calculated using ArcGIS. Models were run using the package unmarked in program R. All models include detection covariates from the top-ranked model for detection (Table 1) and latitude.

Model	**K**	**ΔAIC***	w_i
Maximum angle to horizon	9	0.0	0.72
Maximum horizon quadratic	10	1.9	0.28
Average angle to horizon	9	19.5	<0.001
Null	8	208.3	<0.001
Patch area	9	210.3	<0.001

*log-likelihood of the top ranked model is -2077.979

Using our best model (Table 3), we determined that Saltmarsh Sparrow abundance was negatively correlated with increased angle to the tallest object on the horizon (Figure 2) (β = -1.8; 95% CI = -1.96 to -1.64). The highest predicted abundance of Saltmarsh Sparrows occurred at a maximum angle to the horizon of 0˚, which resulted in an average predicted density of 3 birds per point survey location. At a maximum horizon of 13˚, predicted Saltmarsh Sparrow abundance fell below one bird per point. Between 0 and 13 degrees, Saltmarsh Sparrow density decreased by 0.25 individuals per survey point for every 1-degree increase in maximum horizon angle.

Table 3. Parameter estimates and *post hoc* significance tests of the top-ranked model as determined in the R package unmarked.

Parameter	Estimate	± 95% CI	Z	p-value
detection model				
Intercept	-1.9	0.16	-22	<0.0001
Wind speed	0.08	0.08	1.9	0.06
Survey window	0.06	0.07	1.7	0.10
Noise	-0.15	0.10	-3.0	0.003
abundance model				
Intercept	0.22	0.26	1.7	0.09
Maximum horizon	-1.8	0.16	-22.0	<0.0001
Latitude	-0.06	0.15	-0.8	0.41
Latitude^2	-0.71	0.17	-8.2	<0.0001

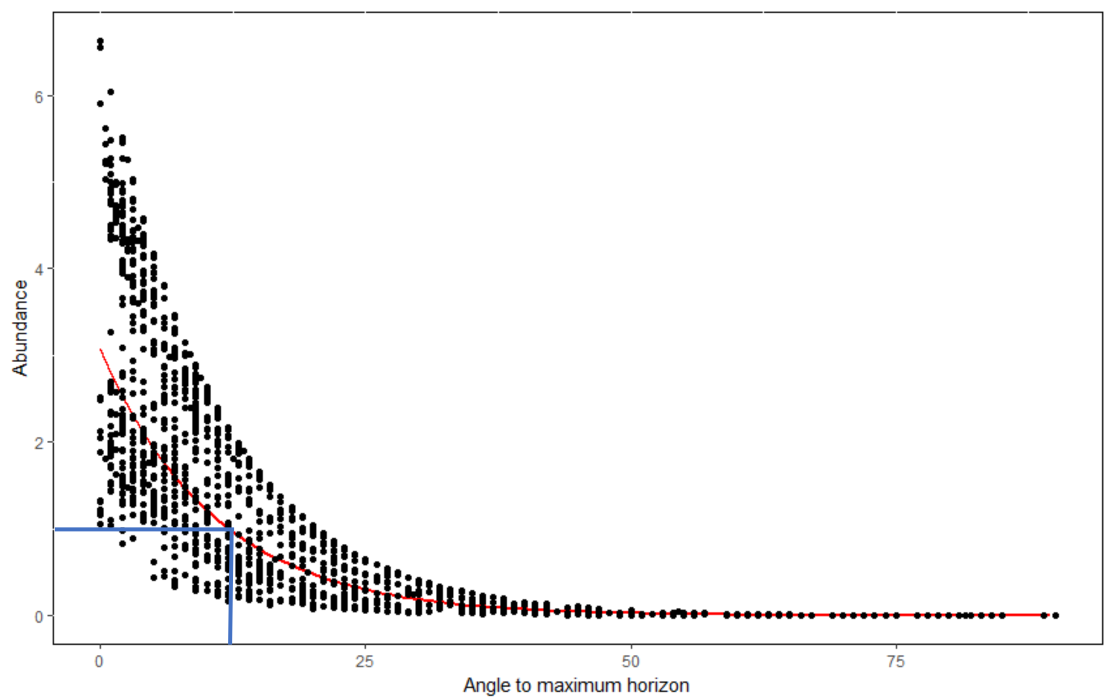

Figure 2. Predicted abundance of Saltmarsh Sparrows as a function of the angle to the maximum horizon. A predicted abundance of one bird occurs at an angle of 13 degrees, and zero birds at approximately 37 degrees. The greatest abundance of sparrows occurs where the maximum horizon angle is zero degrees.

DISCUSSION

Across their breeding range, Saltmarsh Sparrow abundance was highest in more open marsh patches. Although area is correlated with openness, area did not explain variance in our data as effectively as the angle to the maximum horizon. This supports our hypothesis that the angle to the maximum horizon, an index of openness, is a better predictor of Saltmarsh Sparrow abundance than patch area. Saltmarsh sparrow abundance is highest when the angle to the maximum horizon is zero, and the number of birds present at a given point in a marsh declines as that angle increases. The predicted abundance drops below one sparrow at maximum horizon angle of 13 degrees, eventually reaching zero past 35 degrees.

These results provide insight on how Saltmarsh Sparrows may perceive their habitat and make decisions on which patches to use. As an area-sensitive species, it may be that more open marshes are perceived to be larger than irregular-shaped patches that have a greater total area but are bordered by tall objects. Additional factors may contribute to the mechanisms for this behavior, including edge or predator avoidance (Gjerdrum et al. 2008, van der Vliet et al. 2008, Thompson et al. 2014). Openness may be an important additional metric to consider for other marsh and grassland birds, as well as other species exhibiting area sensitivity, as it accounts for both the habitat patch and the surrounding landscape.

It is important to note that we compared abundance to total patch area, while horizon data were recorded from the point count locations placed randomly within patches. Managers should assess the openness of marsh patches by finding the maximum horizon angle from the center of a marsh when making conservation decisions in order to best evaluate the entire marsh patch. There is variation in what is defined as a patch; the scale at which these data are considered by managers should be distinguished to best assess habitat importance (Bakker et al. 2002, Thompson et al. 2014). Our data reflect surveys of nearly 1,700 individual points in over 500 marshes across the entire breeding range of this species, and thus can be applied to all northeastern United States marshes at various scales.

Previous studies suggest that when deciding on habitat to conserve, it may be important to consider nest abundance and success (Vickery and Hunter 1994, Meiman et al. 2012) rather than where abundance of adult birds is highest (Meiman and Elphick 2012), because males and females of this species can be found in patches where nesting does not occur (Meiman 2011). While nesting is an important indicator of patches that contribute to the population, data on nest density and success are more difficult to obtain The ecological use of habitat where the species is present but not nesting is not well understood, but these are generally not patches with high bird densities (C. Elphick, pers. comm.). However, we hypothesize that patches with high bird abundance are more likely to impact population trajectories for a variety of reasons; thus, these patches are likely most important to conserve. Additionally, openness may be a feature which marsh species select for nest placement, as this behavior has been found in grassland species (van der Vliet et al. 2008, Keyel et al. 2013) further supporting the need for conservation of open patches.

Implications for Saltmarsh Management

Saltmarsh Sparrow declines may be used as an early indicator for the fate of the entire community of endemic species using coastal marshes (Correll et al. 2017). North American saltmarsh health and overall area is declining rapidly due to coastal development and other human activities (Wiest et al. 2016). Tidal marshes provide a number of services that are important to humans, including the prevention of flooding and coastal erosion. Thus, degradation of these ecosystems not only poses a serious risk of biodiversity loss, but also threatens human health and economies as well. Conserving this habitat is necessary to prevent the extinction of this species and protect the integrity of North American coastlines.

One place to start is by protecting and improving habitat for the Saltmarsh Sparrow. Our findings imply that birds may perceive marsh area differently from how we measure patch size. We should incorporate measures of openness to more accurately assess the importance of habitat patches. Marshes with a maximum horizon below 13 degrees may be most beneficial to prioritize in order to protect the greatest number of individuals. Managers seeking to improve marsh habitat should remove objects that create a horizon above this threshold, as measured from the central part of a marsh.

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Author’s Biography

Hallie A. Marshall was born in Voorhees, New Jersey on February 28, 1995. She was raised in Atco, New Jersey and graduated from Winslow Township High School in 2013. While attending the University of Maine Hallie majored in Wildlife Ecology with a concentration in Conservation Biology. She is a member of Alpha Lambda Delta Honor Society and the National Society of Collegiate Scholars. She served as the president of the university’s chapter of Circle K International and co-founded the University of Maine Herpetological Society. She also participated in the university’s student chapter of The Wildlife Society and worked as a Learning Assistant for four undergraduate Wildlife Ecology courses. Hallie volunteered as a Student Ambassador for the Department of Wildlife, Fisheries, and Conservation Biology and received an Edith Patch Outstanding Undergraduate Student Award in 2017 for her scholarship and service in the field of science.

Upon graduation, Hallie plans to pursue a Master’s degree and aspires to focus her career on wetland conservation.